Bowtie grating: wave steering in hyperbolic materials

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We present the hyperbolic analog of a bullseye grating that allows simultaneous far-field coupling of all polaritonic states with in-plane hyperbolicity. The grating can reach unity efficiency with high spectral and angular selectivity and exhibits strong field confinement and emission enhancement at its center, leading to a far-field route to polaritonic control in an all-dielectric environment.

General topic. Polaritons present new degrees of freedom in tailoring light at the nanoscale through its rich dispersion assortment in natural anisotropic crystals. Of particular interest are the phonon **polaritons with in-plane hyperbolicity** that show high-quality propagation of deep-subwavelength directional modes on the interface of many low-symmetry Van der Waals materials.

Specific aspect. To harness their supremacy over traditional diffraction-limited light, one first needs **to simultaneously excite all polaritonic states** lying on the hyperbolic dispersion. So far, success with linear gratings has been inherently limited because they can excite only a single state, determined by their pitch and orientation. Here, to couple far-field radiation with the entire hyperbolic branch, which is crucial for many field confinement applications and engineering of local density of states, we present **a new class of surface structure** that acts as the hyperbolic analog of a bullseye grating.

Main results. The proposed grating gets its design blueprint from the two-dimensional inverse Fourier transform of the dispersion hyperbola, and owing to the smooth variation of local pitch and orientation, the grating transfers the correct momenta in all directions, concomitantly. A realistic implementation of the proposed grating, as shown in the Figure below, excites all hyperbolic polariton states on an **alpha-phase molybdenum trioxide** flake when illuminated with normally incident radiation at the design frequency. The absorption spectrum shows an almost **unity coupling efficiency** with a very **high quality factor**. The grating also exhibits **strong angular selectivity** in absorption and a rich anisotropic structure in its thermal emission pattern. Additionally, the grating focuses incident field at its center which leads to **emission enhancement** from single molecules. The proposed bowtie grating opens a new route to far-field polaritonic control in an all-dielectric environment with a broad range of potential applications, from integrated photonics to emitter design.

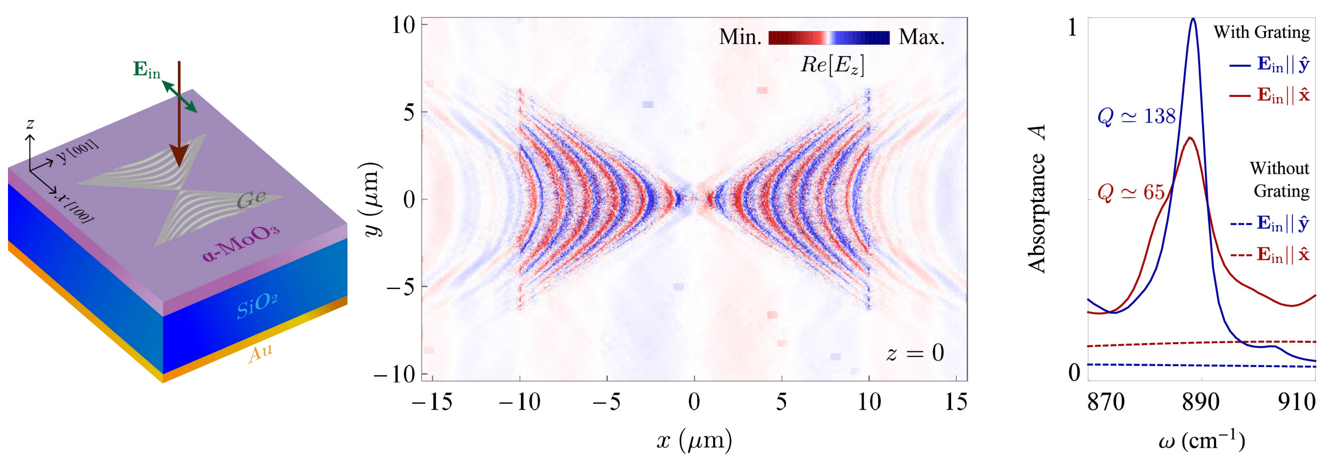

Figure. **Bowtie grating steers incoming plane-wave radiation into assuming hyperbolic wavefronts in polaritonic materials.** Schematic shows (left panel) the absorption setup where a bowtie deposited on α-MoO_3 flake is designed to launch hyperbolic polaritons at a particular frequency upon plane-wave illumination with normal incidence. Top view of the normal component of electric field distribution E_z reveals (middle panel) that excited polaritons, before being absorbed, propagate with hyperbolic wavefronts which clearly indicates excitation of the entire hyperbolic branch of the surface wave dispersion. Absorption spectra for two orthogonal incident polarizations show (right panel) the high coupling efficiency and quality factor of the bowtie grating.